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DETERMINATION OF HEAD LOAD AND POWER REQUIREMENT FOR DEVELOPMENT OF BIN TYPE PADDY DRYER

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ABSTRACT

Harvested paddy grain with high moisture content must be dried to about 12 percent (w. b) within 24 hours for safe storage and milling. The amount moisture evaporated from paddy was 86.64 kg. batch^{-1} of 500 kg paddy dried from moisture content of 25 % (w. b) to 12 % (w. b). The bulk density of paddy was determined 609 kg. m^{-3} at 25.0 % (w. b) moisture content Heat transfer from the paddy was calculated 2.26 MJ kg $^{-1}$ as bottom layer and top layer grain temperature 60^{0}C and 30^{0}C respectively. Total heat was calculated 250 MJ for a period of 8 hours paddy drying. Height of the air column was calculated 247.0 m for pressure drop of 63.17 cm of water. The power requirement for blower calculated as 3.0 Hp for 500 kg paddy bin drying. Based on the design calculation 500 kg capacity paddy dryer was developed.

KEYWORDS: Paddy Dryer, Heat Load & Static Pressure Drop

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Original Article

INTRODUCTION

Rice is the agricultural commodity with the third highest worldwide production of 741.5 million tonnes in the year 2014 after sugarcane and maize crop (FAOSTAT, 2017). India has the largest area under paddy and second largest producer of paddy accounting 22.40 percent of total world production (FAOSTAT, 2013). Andhra Pradesh is the third largest producer of paddy in India and production was 128.95 lakh tonnes during the year 2014-2015, with an average productivity of 3.15 tonnes per hectare from 34.40 m ha. Food grain production in India, 2016 was estimated at 273.38 million tonnes. Production of paddy has increased significantly by 4.74 million tonne (4.54%) than the production of 104.41 million tonnes during 2015-16.

Harvested paddy grain with high moisture content must be dried to about 12 percent (w. b) within 24 hours for safe storage and milling. Approximately 9 percent of paddy was lost due to outdated drying methods, milling, unscientific method of storage, transport, and handling (Basavaraj *et al*., 2015). Drying paddy is one of the major problems in India. Before drying it is necessary to know amount heat requirement, air requirement, and power requirement for better drying. Hence, those calculations were presented in this paper.

MATERIAL AND METHODS

Freshly harvested, local paddy variety *RNR-2458* was selected and procured from Agricultural Research Station, Rajendranagar Hyderabad to conduct the experiments. The paddy was passed through a cleaner and an aspirator to remove foreign matter, broken, chaff, and immature grains.

Moisture Content

The moisture content of paddy samples was determined by drying 10g samples in an oven at 105 ± 1°C for 24 hours (Araullo *et al.*, 1976). The samples were weighed in precision electronic balance having least count of 0.001g. The moisture content was calculated by the loss of moisture per unit weight of paddy.

$$m.c = \frac{W_m}{(W_m + W_d)} \times 100$$

Where

m. c. (w. b.) = Moisture content, %

W_m = Weight of moisture content, g

W_d = Weight of bone- dry material, g

Bulk Density

The bulk density was calculated as the ratio of paddy weight to the volume occupied (AOAC Standard method). Bulk density was measured with 50 ml cylinder, which was filled with paddy up to 15 cm height. The excess paddy was removed and the weight recorded.

RESULTS AND DISCUSSIONS

Initial moisture content was recorded as 25.0 % (w. b) and considered for the study of drying characteristics. Heat load required for design and development of 500 kg capacity paddy dryer was determined to help of physical properties of paddy and air properties. The bulk density of paddy was measured 609 kg. m^{-3} at 25.0 % (w. b) moisture content.The amount of moisture evaporated from paddy was 86.64 kg. $batch^{-1}$ of 500 kg paddy dried from moisture content from 25 % (w. b) to 12 % (w. b) and the total amount of heat required was 250 MJ for a period of 8 hours paddy drying.

Table 1: Amount Moisture Evaporated from Paddy was Calculated

a)	Initial moisture content (w. b.)	=	25%
b)	Final a moisture content (w. b.)	=	12%
c)	Capacity of batch type dryer	=	500 kg
	The amount of moisture to be evaporated from grain	=	500 (1-0.12) $(\frac{25}{100-25})$ x 100 - $\frac{12}{100-12}$ x 100
		=	440 (0.333 – 0.136)
		=	86.64 kg/batch

Table 2: Total Amount of Heat Required for Paddy Calculated as Follows

i)	Temperature of grain, bottom layer	=	60 °C
	Top layer	=	30 °C
ii)	Specific heat of grain, (cp)	=	0.4 kcal kg^{-1} $°C^{-1}$
iii)	Latent heat of vapourization of water	=	540.4 kcal kg^{-1}
		=	2.26 MJ kg^{-1}
iv)	Drying period	=	8 hours
	Sensible heat transfer	=	440 x 0.333 x 1.0 (60-30)
		=	4400 kcal
		=	18.43 MJ
	Sensible heat of grain	=	440 x 0.4 (60-30)
		=	5280 kcal
		=	22.11 MJ

Table 2: Contd.,			
	Latent heat of water vapour evaporated	=	86.64 x 540
		=	46785.6 kcal
		=	195.92 MJ
v)	Total heat required	=	5280.0 + 4400.0 + 46785.6
		=	56,465.6
		$\simeq$	60000 kcal
		$\simeq$	250 MJ
	80 per -cent heat transfer efficiency		
vi)	Rate of heat required	=	$\frac{60{,}000.0}{8\ x\ 0.8}$
		=	9375.0
		=	40 MJ h^{-1}

Table 3: Amount Air Required for 500 Kg Paddy was Calculated with Consideration of Ambient Air Conditions

By using Psychrometric chart air properties were obtained			
i)	Ambient air temperature	=	30 °C
ii)	Relative humidity of air	=	70%
iii)	Absolute humidity of ambient air (H)	=	0.019 kg kg^{-1}
iv)	Humid heat of ambient air, S	=	0.24 +0.45 H
			= 0.24 + 0.45 x 0.019
			= 0.24855 kcal kg^{-1} $°C^{-1}$
			= 1.04 x 10^{-3} MJ kg^{-1} $°C^{-1}$
	Let G be the rate of air supply in kg min^{-1}		
v)	Heat supplied by the hot air in 8.0 hours.		
		=	G. S. $(t_2 - t_1)$ d_t
		=	0.24855 x (45-20) x 480 G
		=	2982.6 G
		$\simeq$	3000 G
	where		
	S is the specific heat of air		
	S	=	0.24855 kcal kg^{-1} $°C^{-1}$
		=	1.04 x 10^{-3} MJ kg^{-1} $°C^{-1}$
	t_2 = Inlet temperature of air to grain (45 °C)		
	t_1 = Outlet temperature of air from grain (20 °C)		
	d_t = Time of drying = 8 x 60		
		=	480 min.
	∴ 3000 G	=	60,000
	G	=	20 kg min^{-1}
	from Psychrometric chart		
vi)	Humid volume of the ambient air	=	0.884 m^3 kg^{-1}
vii)	Air required	=	20 x 0.844
		=	17.68 m^3 min^{-1}
		=	18.0 m^3 min^{-1}
	Cross sectional area of plenum chamber	=	$\frac{\Pi}{4} d^2$
		=	0.785 m^2
	d = Diameter of plenum chamber	=	1.0 m
	h = Height of the plenum chamber	=	0.064 m
	Area of the perforations	=	50 %
	Area through which air passes	=	0.785 x 0.5 m^2
		=	0.40 m^2
	Air required / m^2	=	18/0.40
		=	45.0 m^3 min^{-1} m^{-2}

Table 4: Static Pressure Drop was Calculated for Paddy by the Following Equation (Siebenmorgen *Et. Al*, 1987)

	PD	=	$V (b_1F+b_2M+b_3D+b_4V)$
	where		
	b_1, b_2, b_3, b_4	=	Regression coefficients
	b_1=25.859, b_2= - 90.056, b_3=5.587, b_4=9133.696		
	PD	=	Pressure drop, Pa m^{-1}
	V	=	Velocity, 0.75 m s^{-1}
	F	=	Fines percentage, 10%
	MC	=	Moisture content, 25% wet basis
	BD	=	Bulk density, 609 kg m^{-3}
	= 0.75 (25.589 × 10 -90.056×25+5.587×609+9133.696×0.75)		
		=	6194.95 Pa m^{-1}
		=	63.17 cm of water
	Density of air	=	1.13 kg m^{-3} at NTP
	Pressure drop in terms of air column	=	$\frac{63.17}{100} \times \frac{1000}{1.13}$
		=	559.02 m

Table 5: Capacity of the Blower was Calculated

Blower capacity	=	$\frac{\text{height of air column (m)} \times \text{Air flow rate (kg min}^{-1})}{4500}$
	=	$\frac{559.02 \times 20}{4500}$
	=	2.48 hp
To be on safe side	~	3.0 hp taken

CONCLUSIONS

Initial weight of 500 kg paddy samples was dried from moisture content 25 % (w. b) to 12 % (w. b). The amount moisture was evaporated from grain was 86.64 kg per batch. Heat transfer from the paddy was calculated 2.26 MJ kg^{-1} as the bottom layer and top layer grain temperature 60^0C and 30^0C respectively. Total heat was calculated 250 MJ for a period of 8 hours paddy drying. Height of the air column was calculated 247.0 m for pressure drop of 63.17 cm of water. The power requirement for blower calculated as 3.0 hp for 500 kg paddy bin drying.

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